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(71) Applicant: IOMEGA CORPORATION [US/US]; 1821 West Iomega Way, Roy, UT 84067 (US).

(72) Inventor: STOKES, John, R.; 3930 N. 575 West, Ogden, UT 84414 (US).

(74) Agents: KURTZ, Richard, E. et al.; Woodcock Washburn Kurtz Mackiewicz & Norris LLP, 46th floor, One Liberty Place, Philadelphia, PA 19103 (US).

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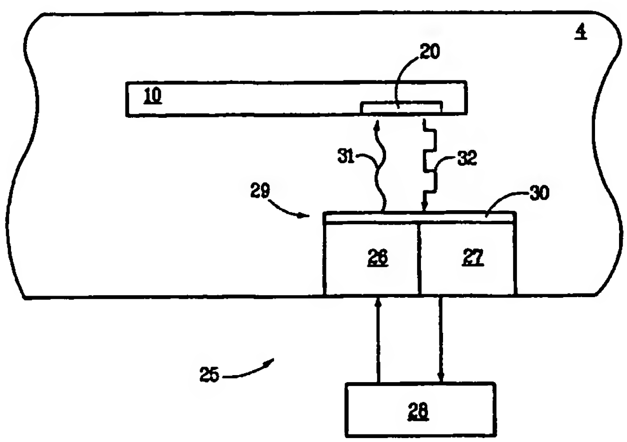
(54) Title: RADIO-FREQUENCY IDENTIFICATION (RFID) TAG FOR DATA STORAGE CARTRIDGES



(57) Abstract: A data storage cartridge for a data storage disk drive has a radio-frequency identification RFID tag. An RF source activates the RFID tag by transmitting an RF signal and the RFID tag emits a response signal. A detector detects the emitted response signal which contains at least one of an encoded ID and one or more characteristics of the disk. The encoded ID and characteristics are forwarded to a micro-controller for discrimination and identification of the inserted object. The RF source and detector are preferably contained in an integrated reader device. The RFID tag and reader device communicate with one another over a RF channel. The encoded information of the RFID tag provides identification of different types or generations of data storage disks or provides a secure keying mechanism for authorized access to proprietary software.

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RADIO-FREQUENCY IDENTIFICATION (RFID) TAG FOR DATA STORAGE CARTRIDGES

FIELD OF THE INVENTION

The present invention relates in general to a marker (hereinafter also referred to as tag) for identifying an object in a system which includes a source of a radio-frequency signal and a detector of a return signal emitted from the marker. More particularly, the present invention relates to a removable data storage disk and to a data storage disk drive for receiving the disk. Even more particularly, the present invention relates to a radio-frequency identification (RFID) tag on the disk for foreign object discrimination and disk detection/identification by the disk drive.

BACKGROUND OF THE INVENTION

Disk drives for receiving removable data storage disks, including conventional 3.5 inch floppy disk drives, must have some mechanism for detecting the insertion or presence of a disk or disk cartridge in the drive. The actuator that carries the recording heads of the disk drive across the recording surfaces of the disk should not be allowed to move unless the presence of an appropriate disk which is non-drive damaging is detected. The removability feature requires that the disk drive have a disk insertion opening into which foreign objects

can be inserted. If these objects physically engage the drive as a legitimate disk would, then the heads could be loaded onto or into the foreign object, thereby destroying or damaging the drive. Also, the spindle motor of the disk drive will be activated by a falsely detected foreign object, thereby generating particle debris.

In the prior art, mechanical switches are typically employed to detect the presence of a disk cartridge within the drive. Such switches are typically positioned such that when a disk is inserted fully into the drive, the disk or disk cartridge contacts the switch, thereby providing an indication that the disk is present.

Markers have also been used to help discriminate foreign objects and to identify disks. "RETROREFLECTIVE MARKER FOR DATA STORAGE CARTRIDGE", U.S. Patent 5,638,228, to Thomas, III, describes the reflection of a highly concentrated quasi circular lobe of light whose spread on reflection is captured by the aperture of a phototransistor in close proximity to a light emitting diode (LED). This emitter/detector pair is in the drive and a retroreflective array is on the disk cartridge. The desired light lobe size is provided by the geometric size of the retroreflector array elements relative to the spacing of the emitter and the detector in the drive. Due to this physical size matching and the fact that retroreflectors are used, this marker on the cartridge is quite insensitive to cartridge tilt and distance from the emitter/detector pair in the drive.

Recently, very small mini-cartridges have been developed for use in miniature disc drives. These mini-drives are incorporated into hand-held devices such as digital cameras, electronic books, global positioning systems, cellular phones and the like. "INTERCHANGEABLE CARTRIDGE DATA STORAGE SYSTEM FOR DEVICES PERFORMING DIVERSE FUNCTIONS", Serial No. 08/746,085, filed November 6, 1996, Edwards, et al. (Attorney's Docket IOM-9319) describes such mini-cartridges, mini-drives, and hand-held devices. This application is incorporated herein by reference.

As disk storage products become smaller and smaller, the need for a cartridge marker of thinner physical size is required. In very thin disk drives where the distance between the cartridge marker and the optical sensing device is very small (e.g., 1 mm), the inherent reflective gain mechanism obtained with a retroreflector over a diffuse or specular reflector is lost. Holographic directional light control is possible, but due to the very small

working distances the ability for false engagement of the drive is significantly increased with that approach.

The ability to discriminate between disk types after insertion into a data storage device but prior to putting the read/write heads on the recording media is of significant value and utility. Principally this utility comes from the ability to detect the difference between various capacities or generations of data storage disks in a downward media compatible data storage drive. This discrimination capability allows for drive/media specific adjustments to be made such as media rotation rate, data channel rates, location of Z track for initial seeking, or even mechanical adjustment in the drive like the active engagement of new crash stop locations. The ability of a disk drive to predetermine the type/generation of data storage disk inserted into it prior to enabling the spin-up and engagement of read/write elements also provides the drive system designer with new possibilities for cross-platform interchangeability.

A "caddy" cartridge, as mentioned in the aforementioned Edwards, et al. application provides cross drive platform compatibility, for example between mini-cartridges and personal computer cartridges. The ability to recognize the installation of a "caddy" into the drive prior to spinning up of the "caddy" and loading of heads is necessary. Again rotational speed adjustments, Z track location information, data channel rate and crash stop/ID and OD data track location information must be determined prior to read/write head loading. This invention provides a solution of these problems also.

Another problem associated with the detection of LED light reflected from any reflective material is the occurrence of illuminance hot spots or structure in the LED output which often results in uneven illumination of the cartridge marker. Reflective cartridge markers can also become faded, scratched, or soiled. These factors combine to make the amplitude of the detected light signal highly variable.

Recently, phosphors have been used in the disk drive industry for the identification and discrimination of disk and disk cartridges in disk data storage drives. "LATENT ILLUMINANCE DISCRIMINATION MARKER FOR DATA STORAGE CARTRIDGES", Serial Number 09/161,007, filed September 25, 1998, Thomas III, et al., describes a system for identifying and discriminating removable data storage cartridges and a data storage drive for receiving the cartridge. In addition, "LATENT IRRADIANCE

DISCRIMINATION METHOD AND MARKER SYSTEM FOR CARTRIDGELESS DATA STORAGE DISKS", Serial Number 09/160,811, filed on September 25, 1998, Krieger et al., describes a phosphor marker for discriminating a cartridgeless type disk object that has been inserted into a disk drive. The systems of each of the above relate to the detection of the presence of the phosphor marker by measuring the time required for the re-radiated light from the marker to decay from one level to another level after the incident light from a light source is removed (e.g., the decay rate). Although the decay rate may provide the basis for discriminating an object that has been inserted into a disk drive, this approach provides an electronically complicated method of detecting the presence of the phosphor marker.

"FREQUENCY BASED CARTRIDGE DETECTION SYSTEM", filed concurrently with this application, Allgood et al., Attorney Docket number IOM-3629, also describes a data storage disk having a latent illuminance discrimination marker for determining whether the data storage disk is suitable for use in a disk drive. A light source illuminates the marker and the marker emits illuminance, preferably as phosphorescence. In this system, a detector detects the emitted illuminance, and a predetermined characteristic of the marker in the frequency domain is determined. The frequency domain response provides identification of different types or generations of data storage disks or provides a secure keying mechanism for authorized access to proprietary software. This method, as well as the above latent illuminance methods, all use light waves to excite and detect the marker. Therefore, they will not communicate through non-metallic materials such as paint, plastic, grease, and dirt, and are more susceptible to light, water, and heat.

Radio-frequency identification (RFID) is currently used in various industries as an alternative means to bar codes for identifying, tracking, and controlling goods and objects. The following is an exemplary list of some of the current trends in transponder systems using RFID: Electronic Article Surveillance (EAS); shipping container and railcar tracking; animal tracking; the labeling of pets so that they can be identified and returned to the owners; implantable and external transponders are being successfully applied in the research of the habits of wildlife, both fish and animals; vehicle access and control; personnel access; production control; ski passes; document authentication; dairy tagging; petroleum and chemical dispensing; and environmental monitoring of the environmental conditions experienced by tagged cargo while in transit.

Although the art of detecting and discriminating between data storage cartridges and of RF identification is well developed, there remain some problems inherent in this technology, particularly when the distance between the disk RFID tag and the RF source and detector device is between about 1 mm and about 15 mm and also in providing an electronically simple system that is accurate and inexpensive. Therefore, a need exists for a tag and system that produces reliable detection and discrimination between data storage cartridges under varying gain and tag spacings.

SUMMARY OF THE INVENTION

The present invention is directed to a disk or disk cartridge for a data storage drive which has a source of a radio-frequency signal at a specific frequency and a detector of a return signal for determining whether the disk or disk cartridge is suitable for use in the drive. The disk includes a body, a data storage medium disposed in or on the body, and a marker disposed on the body. The marker is a radio-frequency identification (RFID) tag which includes a transponder and an antenna device. The transponder includes an integrated circuit having RF processing and memory functions disposed therein. Preferably the RFID tag has an ultra-thin profile or is disposed in the disk body such that the RFID tag does not add significantly to the profile or Z-dimension of the disk or disk cartridge.

The present invention is also directed to a RFID tag system including the RFID tag, a RF source device, a detector of a response signal, and a data processing device. The RF source generates an electromagnetic (RF) signal and transmits the RF signal via an antenna device over the read range of the system. The RFID tag receives the RF signal from the RF source and, in response, emits a response signal having one or more of a predetermined ID code and disk characteristic(s) encoded in the RFID tag toward the detector device. A receiving antenna receives the response signal and sends it to the detector device which formats the response signal for use by a data processing device. The data processing device determines whether the cartridge is suitable for use in that drive and can manipulate selective drive features based on the information contained in the response signal.

The foregoing and other aspects of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The following detailed description of the preferred embodiments, is better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, there is shown in the drawings embodiments that are presently preferred, it being understood, however, that the invention is not limited to the specific methods and instrumentalities disclosed. In the drawings:

Figures 1A and 1B show exemplary data storage disk cartridges having an exemplary RFID tag of the present invention;

Figure 2 is a perspective view of a device in which the invention is used;

Figures 3A and 3B show a plan view of alternative embodiments of the RFID tag of the present invention for use in disk discrimination and identification in a disk drive;

Figure 4 shows a block diagram of an exemplary RFID tag in accordance with the present invention;

Figure 5 shows a side view of an exemplary RFID system in accordance with the present invention for use in disk discrimination and identification in a disk drive;

Figure 6 shows a block diagram of an exemplary RFID system in accordance with the present invention for use in disk discrimination and identification in a disk drive;

Figure 7A is a graph showing an exemplary RF input spectrum for a RFID tag in accordance with the present invention; and

Figure 7B is a graph showing an exemplary output spectrum for a RFID tag in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is directed to a radio-frequency identification marker (hereinafter also referred to as a "tag" or "RFID tag") which is used to discriminate and identify the type of disk (hereinafter also referred to as "disk cartridge") that has been inserted into a disk drive. The present invention provides a radio-frequency (RF) detection mechanism so that it can be ascertained with near certainty that an inserted object is an appropriate disk cartridge. In addition to foreign object discrimination, the RFID tag system can also identify the disk and characteristic of the disk in order to set selected disk drive parameters thereby optimizing the performance of the disk drive for a particular disk. The RFID tag system is a

highly effective discriminant of appropriate cartridge insertion for a disk drive and can also be used to prevent unauthorized copies of software from being easily reproduced and used in disk drives. One means of effecting this software protection is to make the RFID tag alone or in conjunction with data on the storage media a key mechanism which is inserted in the data storage drive for operation of the software. It should be noted that the term RF refers to the source signal which may include signals outside the normal RF range, such as signals higher than RF (e.g., micro-range) and signals lower than RF (e.g., A/C analog signals).

RFID is a non-contact (e.g., wireless) method of storing and retrieving information in a small tag mounted on any object, such as a data storage disk, which requires identification and validation prior to use. RFID tag technology is similar to bar code technology, however the RFID tag is much more sophisticated than the bar code. RFID tags are capable of storing about 100 times the information, in a smaller space, without the environmental problems that bar codes face.

Figures 1A, 1B, and 2 show an exemplary disk and an exemplary disk drive to which the present invention is applicable. The disk cartridge and drive are described in "INTERCHANGEABLE CARTRIDGE DATA STORAGE SYSTEM FOR DEVICES PERFORMING DIVERSE FUNCTIONS", Serial No. 08/746,085, filed November 6, 1996 (Attorney Docket No. IOM-9319), which is incorporated herein by reference.

As shown in Figures 1A and 1B, the disk 10 comprises a disk cartridge having an outer casing 12 and a disk-shaped body having a recording medium 14 which is affixed to a hub 16 that is rotatably mounted in the casing 12. An opening on the bottom shell of the casing 12 provides access to the disk hub 16. A head access opening in the front peripheral edge 18 of the disk cartridge 10 provides access to the recording surfaces of the disk by the recording heads of a disk drive. In accordance with the present invention, a RFID marker, or tag, 20 is positioned on the disk cartridge 10 to be detected by a detector in a disk drive. Although the present invention has been described as being a disk cartridge, the present invention also contemplates that the RFID tag would be equally applicable to cartridgeless type data storage mediums, such as optical disks or CDs. Figure 1A shows a label type RFID tag disposed on the disk cartridge. Figure 1B shows an alternative wedge shaped RFID tag disposed in the casing of the disk cartridge.

Figure 2 shows a laptop computer 2 which has a disk drive 4 for receiving the disk cartridge 10 of Figure 1. The drive 4 may be the Iomega ZIP drive which is disclosed and claimed in the U.S. patents identified in U.S. Patent 5,638,228. This reference is incorporated herein by reference.

Figures 3A and 3B show an exemplary RFID tag 20 for use in the discrimination and identification of a disk 10 by a disk drive 4. Figure 4 shows a block diagram of an exemplary RFID tag. As shown, the RFID tag 20 includes a transponder 21 and a tag antenna 22. The transponder 21 includes an integrated circuit (IC) 23 which includes a receiver device 23a, RF processing 23b and memory 23c functions, and a transmitter device 23d disposed on a transponder chip 21. The transponder chip 21 is preferably a RFID ASIC. The RFID tag 20 provides a wireless link that connects the disk 10 with the micro-controller (not shown) of the disk drive 4 for discrimination/identification of the disk 10.

The RFID tag 20 is activated by a RF signal 31 transmitted from a RF source 26 via a RF antenna 30. In response to the source signal 31, the RFID tag 20 transmits a response signal 32 which is detected by a detector device 27 thereby discriminating/identifying the disk 10. The RFID tag 20 does not actually transmit a signal. The integrated circuit 23 of the RFID tag 20 reflects a portion of the broadcasted RF source signal back to an antenna 30 for the detector 27.

The transponder 21 is the heart of the RFID tag 20 and carries the encoded ID and characteristics of the disk 10. The transponder 21 and tag antenna 22 are preferably contained within the RFID tag 20. The RFID tag 20 preferably comprises a label type RFID tag having an ultra-thin profile (e.g., a minimal height in the Z-dimension of the drive). Alternatively, the RFID tag 20 can be a wedge type or any suitable compact type tag. Preferably, the transponder 21 is adapted and packaged in a variety of sizes and form factors to suit the specific application. Preferably, the RFID tag dimension (Z-dimension) above or below the disk body 12 is preferably very low in order for the cartridge 10 to conform to the thin form factor of the drive 4. Although any device exhibiting RF properties or characteristics can be used in accordance with the present invention, preferably a RFID tag 20 including a transponder 21 having an IC 23 and an antenna 22 is used.

The RFID tag 20 can be any commercially available RFID tag, including a TIRIS Tag-it ™ smart label manufactured by Texas Instruments. The tag's transponder 21

is programmed with a unique ID code and selected disk characteristics. The ID code is preferably contained within an encoded, unique digital code.

Figure 3A shows a Tag-it ™ smart label transponder that offers an ultra-thin form factor that can be laminated into a paper or plastic labels. This label including the RFID tag 20 can then be disposed directly onto the disk body (or medium) 14 or on the disk cartridge 12. The Tag-it™ transponder features read/write capabilities allowing information about the disk 10 to be updated "on-the-fly." This tag also provides for simultaneous identification so that multiple tagged objects may be identified without singulation or orientation. The Tag-it™ RFID tag 20 uses digital protocols to communicate with a detector device. Tag-it™ is a low frequency transponder of about 13.56MHz. Table 1 lists the specifications for the square Tag-it inlay as shown in Figure 3A and also for a rectangle Tag-it inlay (not shown). Alternatively, the tag and transponder can have a circle inlay to conform to the shape of the disk 10 and data storage medium 14. Preferably, the transponder inlay is disposed on the disk cartridge 12 or in those embodiments having a cartridgeless disk, in an area of the disk outside the data storage medium 14. Moreover, the RFID tag 20 can be any desired shape.

Table 1.

Device name:	***Tag-it-Inlay (square)***	***Tag-it-Inlay (rectangle)***
Part number:	***RI-I01-110A***	***RI-I02-110A***
Operating frequency	13.56 MHz	
Memory	256-bit programmable user memory in 8x32-bit blocks	
Antenna size	45 x 45 mm (1.8 x 1.8 in)	45 x 76 mm (1.8 x 3 in)
Tape width	48 mm (1.9 in)	
Foil pitch	48 mm (1.9 in)	96 mm (3.8 in)
Operating temperature	-25 to +70 C	
Storage temperature	-40 to +85 C	
Uplink / downlink data rates	26.7 kBd / 6.2 to 9 kBd secured with CRC	

Device name	Tag-it-Inlay (square)	Tag-it-Inlay (rectangle)
RX modulation	Pulse-width coded, AM 100%	
TX frequencies	Manchester encoded, A = f_c +/ 423.75 kHz, B = f_c +/ - 484.29 kHz Low bit: transition A to B. High bit: transition B to A.	
Thickness (maximum)	Chip and contact: 0.375 mm (o.o15 in) All other areas: 0.085 mm (0.003 in)	
Base material	Substrate: PET (Polyethylentherephtalate) Conductive area: Aluminum	
Smallest bending radius allowed	Chip to reel center: 30 mm (1.2 in) Chip away from reel center: 15 mm (o.6 in)	
Delivery	On cardboard 500 mm (19.7 in) diameter reels Reel width: Approx. 60 mm (2.4 in); inside 50 mm (2 in)	
	-10,000 per reel	-5,000 per reel

The RFID tag 20 is preferably contained in a pressure sensitive adhesive (PSA) sticker. The RFID tag 20 is preferably suspended in an optically clear binder which is coated/printed on the sticker substrate (e.g., white vinyl). PSA with a protective liner is applied to the back side of the sticker substrate.

The RFID tag 20 can alternatively be disposed in a plastic filler for injection molded parts/tags, or applied via suspension in an adhesive compound such as UV curable epoxy, or using any other suitable method. Parts requiring identification and discrimination can be either molded, printed onto, or tagged with the RFID tag 20.

It is desirable that with ordinary handling and abrasion the RFID tag 20 will not flake, peel, or otherwise be damaged in a manner to adversely affect its performance or generate debris which could adversely affect a disk drive's performance. Moreover, preferably, the tag 20 is operational from about -20 to about 65°C (about -4 to about 149°F)

and has a functional life of at least 15 years. Thus, a passive RFID tag 20 is preferred as the disk marker 20.

Figures 1B and 3B show another exemplary tag 20 and transponder 21. This compact wedge type transponder 21 offers an ultra-compact package that may be disposed within the disk body 12. The tag 20 can be any size or shape that fits on the disk cartridge 12, with the thickness, preferably less than about 3.0 mm and a thickness tolerance of about ±0.05 mm. Figure 3B shows a perspective view of an exemplary wedge type RFID tag 20 having the preferred physical dimensions of the tag implementation for a cartridge application, with dimensions: length L equals approximately 12 mm, width W equals approximately 6 mm, and height H equals approximately 3.0 mm.

Figure 5 shows an exemplary RFID system 25 in accordance with the present invention. The RFID system 25 includes the RFID tag 20, a RF source 26, and a detector 27 of RF for discriminating/identifying an object, such as a disk 10, that is inserted into a disk drive 4. Although not a requirement, the RFID tag 20 is preferably disposed on the disk body 12,14 such that the RFID tag 20 is positioned proximate the RF source 26 when the disk 10 is inserted into the disk drive 4. The RFID tag 20 may be located on a top surface or a bottom surface of the data storage medium 14, disk 10, or disk cartridge 12. On each disk cartridge 12 having an authorized copy of the software, there is a RFID tag 20 which preferably includes at least one of an encoded ID and disk operating/storage characteristics that serve to identify the type or generation of disk and distinguish it from other types of disks.

Radio-frequency identification is an advanced automated data capture, processing, and communications technology. RFID is an automatic identification technology, similar to bar code technology, with positive identification and automatic data transfer between a tagged object and a reader. RFID uses radio-frequency (or RF), which is a type of electromagnetic energy that is transmitted in the form of waves that increase or decrease in amplitude or size. The RFID tag 20 of the present invention contains information about the disk 10, including the disk ID code, as well as, information relating to the disk's operating and data storage characteristics. Since the RFID tag 20 is read by low wattage radio waves, instead of light waves (as with bar-codes and latent illuminance type disk discrimination systems), it will communicate through non-metallic materials such as paint, plastic, grease,

and dirt, and is less susceptible to vibration, light, water, and at higher temperatures in most cases.

As shown in Figure 5, the RFID system 25 includes a RFID tag 20, a RF source device 26, a detector device 27 of a tag response signal, and a data processing device 28, such as a computer. Any RF source can be used that puts out RF sufficient to energize the transponder 21 of the RFID tag 20. The RF source 26 and the detector 27 are preferably integrated into a single reader device 29. The RF source 26 interrogates the RFID tag 20 by broadcasting RF energy (a RF source signal 31) via a transmitting antenna 30 over a fixed or adjustable area. This broadcast area may be referred to as the read zone or reader footprint. The RFID tag 20 on the disk 10 reflects a small part of the RF energy back to a receiving antenna 30 coupled to the detector 27. The detector antenna can be a separate antenna (not shown), or preferably is the same integrated antenna 30 used by the RF source 26 to broadcast the RF signal 31. The detector 27 is capable of detecting a return signal 32 from the RFID tag 20 and communicating this information to a data processing device 28, such as a micro-controller, for processing of the response signal 32. The response signal 32 can be used to discriminate the tagged object and to manipulate one or more computer processes, including activation or deactivation of the disk drive 4 or a drive function.

The RF source 26 and detector device 27 can be provided a single reader device 29 within the disk drive 4. The reader 29 and integrated antenna 30 work together to generate, transmit, receive, and read the RF transmissions. Preferably, the reader 29 generates the RF signal 31 and sends this request for identification information to the tag 20. The RFID tag 20 responds by transmitting the response signal 32 with the respective information, which the detector 27 portion of the reader 29 receives and formats, and then forwards to the data processing device 28. The model, size, and packaging of the reader 29 and antenna 30 are preferably determined based on the particular application.

The reader device 29 is an integrated device including the RF source 26 and the detector 27. The reader 29 performs several functions, including producing a low-level radio-frequency magnetic field. The RF magnetic field can service as a "carrier" of power from the reader 29 to a passive RFID tag 20. When the RFID tag 20 is brought into the magnetic field produced by the reader 29, the recovered energy powers the integrated circuit (IC) 23 in the RFID tag 20, and the memory contents of the RFID tag 20 on the disk 10 are

transmitted back to the reader 29. Once the reader 29 has checked for errors and validated the received data, the data is decoded and restructured for transmission to a data processing device 28 in the format required by the computer system (not shown).

More particularly, the reader 29 includes the hardware and the software for generating, transmitting, receiving, and formatting a RF signal. The reader 29 hardware includes a RF source device 26 for generating a RF signal 31 and for transmitting the RF signal, and a detector device 27 for receiving and detecting the response signal 32 from the RFID tag 20. The reader 29 also includes software for controlling the operation of the reader 29 and for formatting the response signal 32 for transmission to the data processing device 28. Alternatively, each of the devices described above can be a stand-alone device that are electrically or electro-magnetically (RF) coupled together.

The reader 29 of the present invention can include any low cost, physically compact commercially available readers, such as the TIRIS S2000™ and the TIRIS Micro-reader™ made by Texas Instruments. Each of the above readers provides a compact miniature size for efficient integration, offer standard hardware and software for easy of design, and are fully compatible with the low frequency transponders.

Normally, the performance or read range will diminish when mounting the reader 29 on or near metal. Preferably, the reader 29 is pre-metal compensated, meaning that it can be mounted on any materials, including metals such as aluminum and steel doorframe with minimum degradation. The reader 29 is preferably installed in the disk drive housing in a manner which ensures that the metal stand off is a maximum allowable distance from the reader 29 and preferably does not cover up the front face of the reader 29.

The tags' transponder 21 and the reader 29 communicate with one another over a RF channel. The RFID tag system 25 provides flexibility over other types of disk discrimination system in that direct line of sight is not required between the tag 20 and the reader 29 and also due to the fact that the reader 29 can be located some distance away from the RF source device 26 or module and antenna 30. In addition, the link between the reader 29 and the computer can be wireless. The entire disk discrimination/identification process takes only milliseconds thereby minimizing the amount of disk spin-up, if any.

Integral with the RFID tag system 25 is one or more antennas 30 for broadcasting the RF signal 31 and for receiving the response signal 32 between the reader 29

and the RFID tag 20. The one or more antennas 30 function to transmit the RF signal 31 that interrogates the RF tag 20 and also to receive the response signal 32 sent by the RFID tag 20. The antenna 30 is coupled to the RF source 26 and to the detector device 27 that processes the ID code returned by the tag 20.

Preferably a single integrated antenna 30 is disposed proximate the reader device 29 and is used to both send and receive the RF energy and data between the reader 29 and the RFID tag 20. Alternatively, separate antennas can be provided, one for transmitting the RF signal 31 from the reader 29, and one for receiving the response signal 32 from the RFID tag 20.

The antenna 30 can comprise any suitable transmission and receiving device including a ferrite rod antenna which is a short cylindrical device or a gate type antenna. The type of antenna is preferably selected to match the design requirements and preferred read range of the RFID system. A gate antenna is well suited for tight areas where reading field coverage needs to be maximized. Preferably, the antenna 30 of the present invention is a ferrite rod antenna which is well suited for stationary applications where space is limited or the antenna is mounted in close proximity to the RFID tag 20.

Preferably, the data processing device 28 comprises the existing microprocessor of the disk drive 4. The microprocessor is adapted to receive an output signal from the detector 27 portion of the reader 29 and to determine the validity and characteristics of the inserted disk 10.

Figure 6 shows a block diagram of the exemplary system 25 of Figure 5. As shown, the RF source 26 activates the RFID tag 20 by emitting a RF signal 31 when the disk 10 is inserted into the disk drive 4. The RF source 26 can be continuous or may turn on as the disk is inserted and then turned off. The RF source 26 is preferably driven by RF source switching and current limiting electronics (not shown), and a microprocessor 28 which sends pulse commands to the electronics.

In response, the RF tag 20 emits a response signal 32, having an encoded information relating to the disk, back toward the detector device 27 in response to the RF signal 31 received from the RF source 26. The response signal 32 can have an intensity value at a particular wavelength or wavelengths, which is detected by the detector 27.

Gain, preferably 100X, is applied to the output of the detector device 27 by a gain stage 33. The output of the gain stage 33 is provided to a comparator 34 which compares the emitted illuminance with a predetermined disk ID code or disk characteristic. The results of the comparison are provided to the microprocessor 28 which reads the formatted response signal and identifies the disk 10 for validation, as described above.

During operation, the RF source transmitter 26 sends out an electromagnetic wave (e.g., a RF signal) via the antenna 30 to establish a zone of surveillance and interrogate a RFID tag 20. When a RFID tag 20 enters this zone, the electromagnetic energy from the reader 29 begins to energize the IC 23 in the RFID tag's transponder 21. Once the IC 23 is energized, it goes through an initialization process and begins to broadcast its identity. Preferably, this process utilizes a low energy, back-scattering technology that selectively reflects or back-scatters the electromagnetic energy back to the reader 29. The receiving and detecting circuits 27 in the reader 29 sense and decode this back-scattered signal, identify the RFID tag 20, and then determine whether the disk 10 is suitable for use in the disk drive 4. In addition, the proper drive settings for that particular disk 10 can be determined based on the tag's response signal 32.

Alternatively, the reader 29 can use a wand or reading head to send an inductive voltage to the RFID tag 20. Once the RFID tag 20 is powered, a miniature microprocessor inside the RFID tag 20 starts a communication session with the reading head. At this point the RFID tag 20 will either send its stored data, or be updated with new data depending on the wishes of the user.

Figure 7A is a graph illustrating an exemplary RF source signal 31. As shown, the RF source signal 31 is preferably an analog signal having a predetermined frequency and amplitude.

Figure 7B is a graph illustrating an exemplary response signal 32 in accordance with the present invention. Although the response signal 32 can be an analog or a digital signal containing the disk ID code as well as other characteristics of the disk, it is preferably a digital signal. In those embodiments where the response signal 32 comprises an analog signal, the response signal is preferably at a different wavelength than the RF source signal 31.

Table 2 below is a comparison of a RFID tag system to other identification systems.

Table 2.

RFID Compared to Competing Technologies	RFID	Infrared	Bar-Coding
Amount of information stored and transmitted	**HIGH**	High	Low-Medium
Information can be transferred through dirt, grime, grease, paint, some metals and other materials	**Yes**	No	No
Maximum distance of transmission (feet)	**120+**	˜30	˜3
Required line-of-sight transmission	**No**	Yes	Yes
Tags are Read/Write	**Yes**	Yes	No
Tags can be used integrated into security applications	**Yes**	No	No

RFID systems can be classified according to the frequency band in which they operate, as either high, intermediate, or low. RFID systems can further be broken down according to some characteristics of the tags being used, such as how the tag is powered, the type of memory, etc. The tag may be classified based on how it is powered as one of an active tag and a passive tag. In addition, the RFID system can be classified according to its memory type as one of read-only, write-once-read-many (WORM), and read-write.

The RFID tag 20 of the present invention can be either active or passive. The classification of active or passive describes the power of the tag. Preferably, the RFID tag 20 of the present invention is a passive tag (e.g., battery-less) which is powered by the reader signal. A passive RFID tag is totally powered by the magnetic field generated by the reader 29. The incoming radio signal which "wakes the tag up", energizes the RFID tag 20, and provides sufficient power for the RFID tag 20 to respond with its requested data. This contributes to very high reliability and long service life, which allows for the RFID tag 20 to be mounted one time during the life of the disk 10 and allows the RFID tag 20 to be mounted in many more locations than other devices that need maintenance or battery replacement. A

passive RFID tag 20 is preferred due to the fact that this type of tag can be very small and they have a sufficient range for the application of the present invention where the distance between the reader 29 in the disk drive 4 and the inserted disk 10 is much less than the range of the RFID tag 20. Passive tag systems typically use frequencies in the 120 to 130 kilohertz (kHz) range.

Alternatively, the RFID tag 20 can be an active tag. An active RFID tag has an on-board power source, such as a battery. The advantage of an active tag is that it reduces the power requirements of the reader, and it can transmit its information over relatively far distances. The disadvantages are that it has a limited operating life, can only be used in certain environments, and is more expensive than a passive device. An active RFID tag system typically uses frequencies in the 900 MHz to 2.45 GHz range. For both the passive and active RFID tag systems the tag and reader communicate in milliseconds.

As stated, there are several memory types available for the RFID tag 20, including read only, write-once-read-many (WORM), and read/write. Preferably, the RFID tag 20 of the present invention is a read-only tag. Data or information in the read-only tag is programmed at the factory and cannot be altered in the field during operation. Once the read-only tag is properly identified, a device, such as a computer containing the disk drive, may instruct the disk drive what action to perform on the disk. Preferably, the read-only RFID tag provides an unalterable 20-digit (64 bit) unique digital code which is permanently programmed at the factory during manufacturing.

A write-once-read-many (WORM) RFID tag 20 allows the user to write to the tag once to encode certain disk features, such as the disk ID, disk capacity, spin rate, disk density, Z track location information, data channel rate, crash stop/ID and OD data track location information, and updating information codes, such as times and dates. This encoded information can then be read as many times as desired over the life of the disk.

Alternatively, the RFID tag 20 can be a read/write RFID tag. This type of tag allows the user to write to the RFID tag to encode certain disk features, such as the disk ID, disk capacity, spin rate, density, etc. The read/write system can also read and change, or add information to the tag as they come into proximity of the reader. The encoded information can be read as many times as desired over the life of the RFID tag and the disk.

A typical read/write RFID tag contains a single 64 bit memory area that can be programmed by the user. It is for application where an arbitrary number is inconvenient, where the security of hard factory programming is not needed, or where data needs to be changed during the tag lifetime, then read/write functionality is preferred. This type of RFID tag allows the user to write to or read from the disk as many times as desired over the life of the disk.

Read range, or the maximum distance away from the reader 29 at which the RFID tag 20 may be read, is generally a function of the antenna 30 size within the reader 29 and the tag's antenna 22 for a given operating frequency. The inductance resonate (for low frequencies) to a capacitor (not shown) within the reader 29 and the tag 20 for a given operating frequency also affects the read range. In general, a larger antenna in area measurement of reader and tag, higher voltage and/or better resonate to the operating frequency usually provide greater read range.

RFID requires only proximity between the reader 29 and RFID tag 20 for a successful read because there is no requirement that there be direct line of sight between the reader 29 and the RFID tag 20. This allows greater placement flexibility in locating the reader 29 within the disk drive 4 and in locating the RFID tag 20 on the disk 10. Read range is determined by two key elements, the antenna and the power applied through the antenna. Stationary antennas can be large which can result is a long read range up to 36 inches for low frequency transponders.

The performance of the RFID system 25 is impacted by the different frequencies under which it operates. Low frequency systems (< 500kHz) generally have a read range of about 6 feet and below and a data rate of about 1-10KB/s. High frequency tags (> 500kHz) have a read range of about 100 feet and a higher data transfer rate of between about 1KB-10MB. High frequency systems are more susceptible to interference from other RF systems operating within the same range (e.g., cellular phones) and to the environment. Preferably, the RFID tag 20 of the present invention operates in the low frequency range due to the short read range between the RFID tag 20 and the reader 29. The short read range is a result of the relatively close proximity of the RFID tag 20 on the disk 10 to the reader 29 in the disk drive 10. Also, a low frequency range is preferred to minimize the costs associated with the disk discrimination and identification system. The low frequency RFID tag should

FREQUENCY	LF 30-300KHz	HF 3-30MHz	VHF 30-300 MHz	UHF 300-1000MHz	MICROWAVE 1GHz and Up
"Skip" Interference Tropo Ducting	None	High	Low	Lower	None
Electrical Interference	Very High	High	Medium	Med to Low	Low
Distance	Less than 2 meters 1cm - 1.5m typical	Less than 1 meter 1cm - .7 m typical	1-100 meters 1-3m typical	1-100 meters 1-3m typical	1-300 meters 1-10m typical
Date Rate	1-10KB/s	1-3KB/s*	1-20KB/s	1KB-10MB/s	1KB-10+MB/s

* (Depends on regulations and distance. At very close spacing like smart cards, higher data rates are possible.)

Reflection is signal reinforcement or cancellation (nulling) due to direct and reflected signals being in or out of phase based on distance between the RF source and the target RFID tag and the length of the reflected path. Enhancement is usually only plus 3 to 9 dB. While nulling can be total, nulls are usually -10 to -30 dB. However, signal fill caused by the multiple reflections often found in most indoor environments will generally reduce nulling losses to -6 to -12 dB or so.

Blocking (not in table 4) on the other hand, can be total in some locations. Blocking occurs when an object larger than a half wavelength gets between the RF source and the RFID tag and shadows the tag completely from the source. This will be more of a problem at higher frequencies (microwave) than at lower frequencies (LF, HF or VHF) but may also be a plus in systems where floor or wall penetration by the signal is not desired.

Skip Interference / Tropo refers to out of area signals which may arrive at levels quite strong compared to the desired local signal due to refraction from the earth's ionosphere (HF) or tropospheric ducting (VHF / UHF). Tropospheric ducting occurs along the boundary between air masses of different temperatures. This phenomena is usually not a problem in the present invention due to the close proximity of the RFID tag to the reader once the disk is inserted into the disk drive.

RF tags 20 generally fall into three broad categories, including inductive, Back Scatter, and Two-Way RF tags. Inductive tags are energized by passing through an energizing field generated by the reader. The tag resonates at the frequency of the field causing a disruption of the field. These tags have minimal information storage capabilities. This type of RF tag is the lowest in cost. Typical read ranges are less than about 10 feet.

Back scatter tags may be either passive (no battery) or active (battery powered). They reflect a small portion of the RF energy of the reader. The reflected signal is modulated or encoded with information stored in the tag. Back scatter tags generally cost more than inductive tags.

Passive back scatter tags convert a portion of the RF energy from the reader to power the transponder. The tag generates a data stream, typically including a clock signal and the data stored in the tag.

Back scatter tags are capable of being programmed with varying amounts of information. Some tags may be re-programmed by a reader, others have the ability to store additional data from readers to their internal memory.

Two-Way tags are active tags which incorporate a miniature transmitter and/or receiver. The tag may be polled or transmit freely. Data may be read only or programmed by the interrogator. These are the most expensive type tag.

Grounding is desired for proper operation of the reader 29. When installing the reader, an earth ground is preferred. Alternatively, an AC main power ground can be used. Preferably, the resistance should be less than about 50 ohms. For multiple readers installation, it is preferred that all readers are connected to the same grounding system. Using different grounding systems may create secondary current paths or ground loops that can affect the performance and cause damage to the reader.

The distance between the RFID tag 20 and the RF source 26 is preferably in the range between about 1 mm and about 15 mm. The read range of the RFID tag system is preferably from about 1mm to about several meters. Accordingly, when the disk 10 is inserted into the disk drive 4, the RFID tag 20 on the disk 10 is well within the read range of the RFID tag system 25.

In accordance with the present invention, it is desirable to minimize the spin-up time for the disk drive. Minimization of the spin-up time dictates the time duration of transmission of the RF source signal and the RFID tag response signal be as short a duration as possible. The time duration between the reader activating the RFID tag and the validation/identification of the disk is on the magnitude of milliseconds and therefore this discrimination/identification process provides a minimum spin-up time for the disk drive to perform the validation/identification function.

A series of different RFID tags (e.g., 10 to 20) can be formulated for a particular user such as a software manufacturer, with each formulation having different RF characteristics and therefore each will respond to different RF source signal and relay its unique encoded disk characteristics. The decomposition and reverse engineering required to reformulate a RFID tag of the present invention is difficult. In the event that such a security break does occur, however, the software manufacturer can switch to another RFID tag having a different signature. These other signatures would be programmed or encrypted into the drive's firmware as a recognizable RFID tag. Thus, the present invention can be used by a software manufacturer to identify its program disks as being authentic, so that only authorized users could use the software stored on those disks. Alternatively, the RFID tags' detection alone or in conjunction with the data store on the disk can act as a key mechanism to allow authorized use of the proprietary software. If the appropriate cartridge is not inserted, access to the use of the software is denied.

As stated above, it is most preferred that the response signal 32 be different or shifted from that of the source 31 (e.g., the source emits an analog RF signal and the transponder emits a digital response signal). Secondarily, when using a series of different RFID tags, it is preferred that all the tag types' RF spectra be within the responsivity window of the detector. At a minimum, the RF characteristics of the tag types preferably are within the response spectrum of the detector.

The response signal for different generations of disks can be produced by using different encoded transponders which would have different encoded information based on their individual characteristics.

One embodiment in accordance with the present invention incorporates a filter (not shown) to filter out the RF at the aperture of the detector and only transmit the response signal(s) that are to be emitted by the transponder of the RFID tag. This reduces the recovery time required by the detector to come out of saturation from the source RF and makes the system less sensitive to ambient light sources.

The detector 27 may have a very broad wavelength excitation range which makes it more difficult to detect specific responses. A filter material to remove the RF source signal can be placed on the detector. This helps absorb any reflected RF source signal that results from the RF source signal used to activate the RFID tag's IC (i.e., the reflected RF is the electro-magnetic source signal that is not absorbed and "reflected" as a response signal by the RFID tag). If the RFID tag does not convert the RF source signal to the response signal, the RF will be absorbed by the filter, thereby preventing the creation of DC bias in the detection circuitry.

Therefore, the transponder is charged by RF having an analog feature. The RFID tag transponder emits a response signal having a digital characteristic. The detector filters the source RF analog signal and detects only the emitted digital response signal from the RFID tag. Thus, the detector performance is improved by minimizing or reducing the effect of the RF source on the detector, thereby improving the aggregate system response.

Another feature in accordance with the present invention is the use of a filter, preferably a high pass electronic filter or a notch filter, on the detection circuit to filter out ambient RF. This prevents noise from affecting the response signal.

The present invention can be used to identify read-only disks, write once disks, and disks having particular applications, such as photodisks for digital camera applications, global positioning or map disks, and book disks.

RFID is an automatic identification technology that speeds the collection of data and eliminates the need for human operations in the process. With RFID technology, no line of sight or direct contact is required between the reader and the tag. Since RFID does not rely on optics, it is ideal for dirty, oily, wet or harsh environments. RFID tags and readers

have no moving parts and therefore the system rarely needs maintenance and can operate flawlessly for extended periods of time. Passive RFID tags have an extremely long life, usually 10 years or more, and will usually outlast the asset to which they are attached. RFID is fast, the RFID tag and reader communicate in milliseconds. RFID provides an inexpensive form of automatic identification when evaluated over time.

The RFID tags of the present invention are less complex and more economical to manufacture than other types of marker systems used for disk discrimination in a disk drive. The RFID tag system is very fast and highly repeatable and thus provides a manufacturing advantage.

Although the present invention has been described herein with respect to cartridge detection, it can be used in any object detection or discrimination apparatus or application, such as anti-counterfeiting apparatus and applications.

Although illustrated and described herein with reference to certain specific embodiments, the present invention is nevertheless not intended to be limited to the details shown. Rather, various modifications may be made in the details within the scope and range of equivalents of the claims and without departing from the invention.

What is claimed:

1. A disk for a data storage disk drive which has a RF source and a detector of a response signal for determining whether said disk is suitable for use in said drive, said disk comprising:

a body;

a data storage medium in said body; and

a RFID tag on said body, said RFID tag receives a RF signal from said RF source and, in response to said source RF signal, emits a response signal toward said detector for detection which thereby identifies said disk as being suitable for use in said drive.

2. The disk of claim 1, wherein said response signal includes one or more of an encoded ID code and at least one disk characteristic which is used to identify said disk.

3. The disk of claim 1, wherein said RFID tag response signal is used for one of discriminating a disk for use in said drive and manipulating one or more drive settings.

4. The disk of claim 1, wherein said RFID tag further comprises a transponder and a tag antenna.

5. The disk of claim 4, wherein said transponder comprises an integrated circuit having RF processing and memory functions which contain an encoded ID code and at least one disk characteristic.

6. The disk of claim 4, wherein said tag antenna comprises a transmitter and a receiver.

7. The disk of claim 1, wherein said RFID tag is a passive RFID tag.

8. The disk of claim 1, wherein said RFID tag comprises a read only RFID tag.

9. The disk of claim 1, wherein said RFID tag comprises a low frequency RFID tag.

10. The disk of claim 9, wherein said low frequency RFID tag operates in a low frequency band between about 30kHz and about 300kHz.

11. The disk of claim 1, wherein said RFID tag is one of coated on a pressure sensitive sticker substrate and suspended in one of an adhesive compound and a glue.

12. The disk of claim 1, wherein said RFID tag is injection molded in said disk.

13. The disk of claim 1, wherein said RF signal from said RF source comprises an analog signal.

14. The disk of claim 1, wherein said RFID tag response signal comprises a digital signal.

15. The disk of claim 1, wherein said data storage medium further comprises a cartridge type data storage medium having a disk-shaped recording medium rotatably mounted within said body.

16. The disk of claim 1, wherein said RFID tag is positioned on said disk such that it does not contact said source of RF or said detector of a response signal.

17. The disk of claim 1, wherein said RFID tag has a read range between about 1 mm and about 15 mm.

18. The disk of claim 1, wherein said RFID tag response signal comprises a portion of said RF source signal which is emitted back to said detector device by said RFID tag.

19. A system for the discrimination and identification of a disk for use in a disk drive, said system including:

a RF source;

a detector of a response signal;

a processor; and

a disk, said disk comprising:

a body;

a data storage medium in said body; and

a RFID tag on said body, said RFID tag receives a RF signal from said RF source which activates said RFID tag and said RFID tag emits a response signal in response to said source RF signal having an encoded message toward said detector for detection which thereby identifies said disk as being suitable for use in said disk drive.

20. The system of claim 19, wherein said RF source and said detector of a response signal are integrated into a reader device.

21. The system of claim 19, wherein said RF source and said detector are disposed within a housing of said disk drive.

22. The system of claim 19, wherein said RF source comprises an antenna and a transmitter device that interrogate said RFID tag by sending a RF signal containing a request for identification information to said RFID tag.

23. The system of claim 22, wherein said RFID tag has a response signal, said response signal being emitted by said RFID tag in response to said request from said RF source, said response signal containing the requested information regarding said disk toward said detector device.

24. The system of claim 23, wherein said detector device comprises an antenna and a receiver device adapted to receive said response signal, format said response

signal for use by said processor, and forward said formatted response signal to said processor which discriminates and identifies said disk as suitable for use in said disk drive.

25. The disk of claim 24, wherein said processor is an existing micro-controller for said disk drive.

26. The system of claim 19, wherein said RF source, said RFID tag, and said detector device communicate with one another over a RF channel.

27. The system of claim 19, wherein said RF source signal is an analog RF signal.

28. The system of claim 19, wherein said RFID tag response signal is a digital RF signal.

29. The disk of claim 19, wherein said RFID tag includes a transponder having an integrated circuit and a tag antenna, said integrated circuit including a receiver device, RF processing and memory functions, and a transmitter device.

30. A method of discriminating and identifying a disk for use in a disk drive, said method comprising the steps of:

providing a disk drive having a reader device disposed therein;

inserting a disk having a RFID tag disposed thereon into said disk drive;

emitting a RF signal from said reader device toward said RFID tag;

responding to said RF signal by emitting a response signal from said RFID tag toward said reader device; and

discriminating and identifying said disk for use in said disk drive based on one of an encoded ID and a disk characteristic contained in said response signal.

FIG. 1A

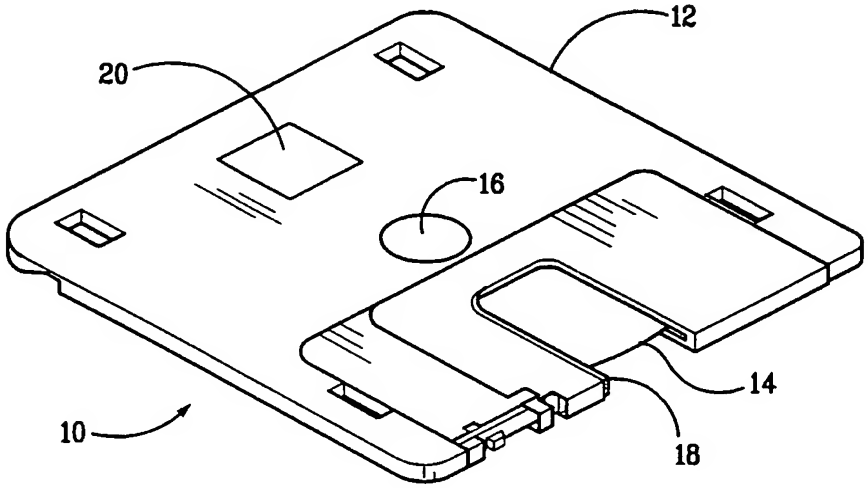
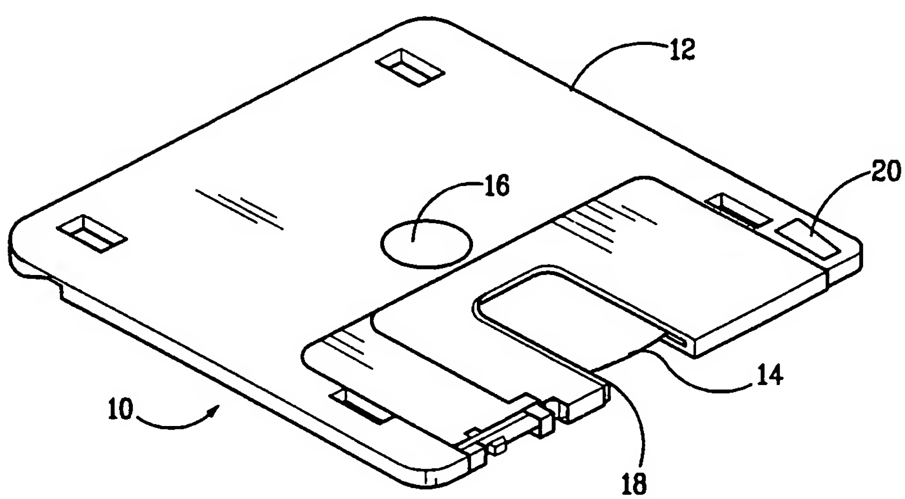


FIG. 1B



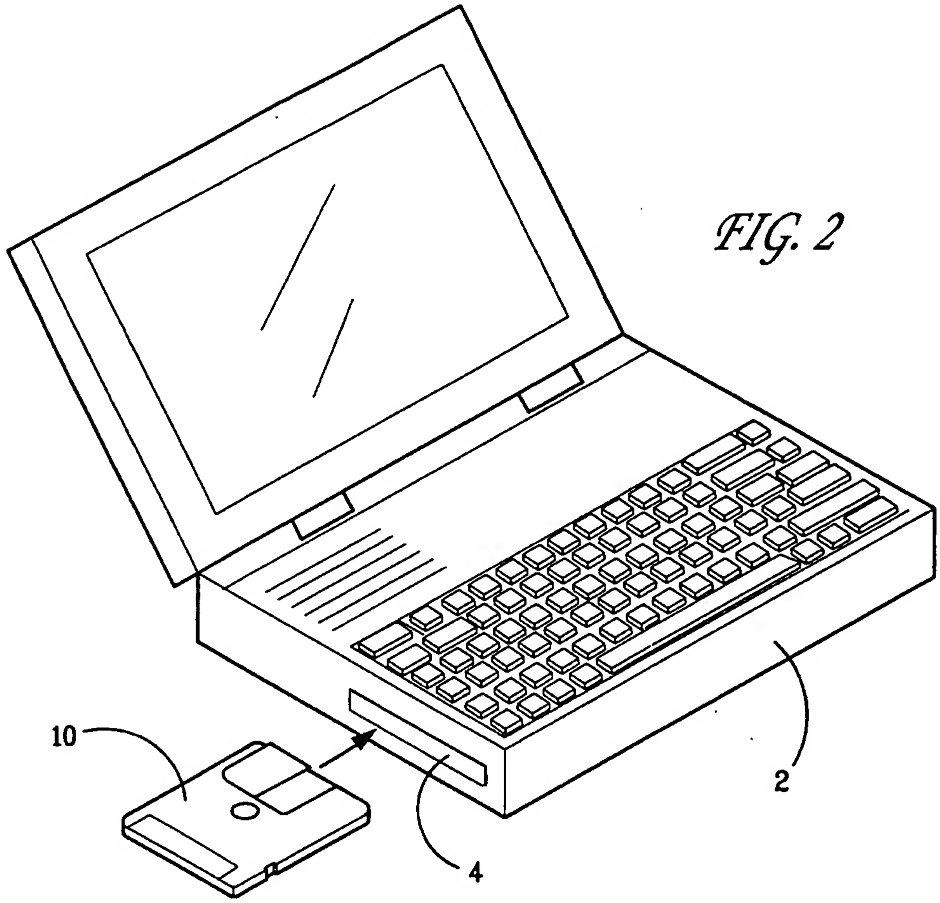


FIG. 2

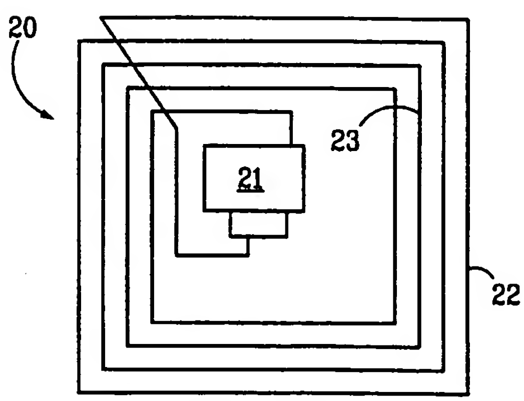


FIG. 3A

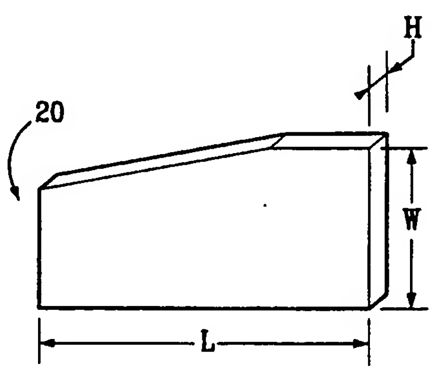


FIG. 3B

FIG. 4

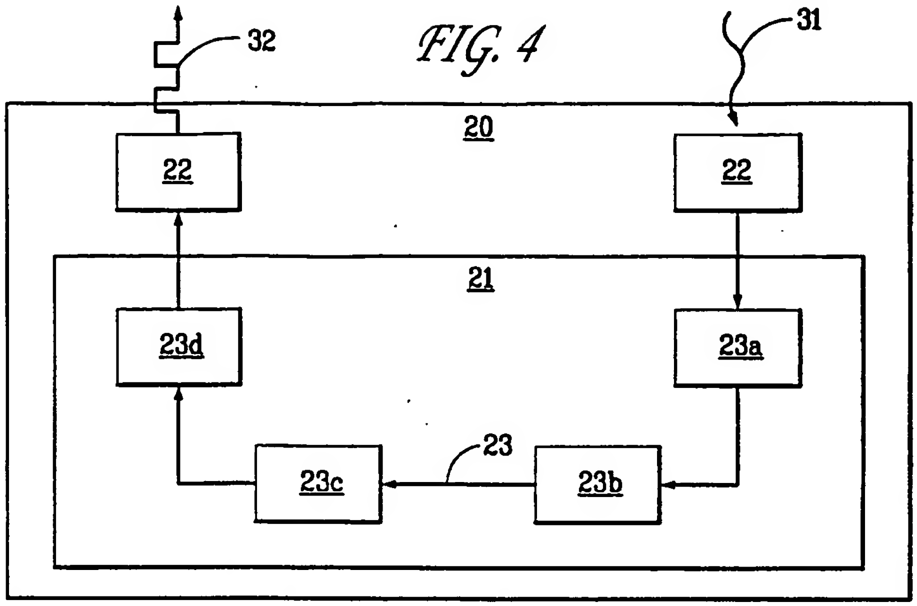


FIG. 5

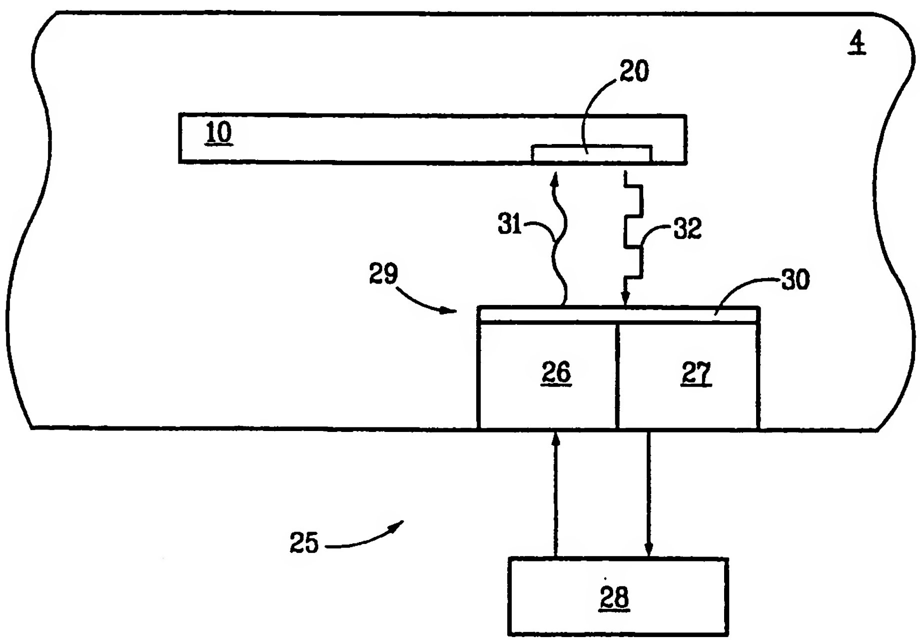


FIG. 6

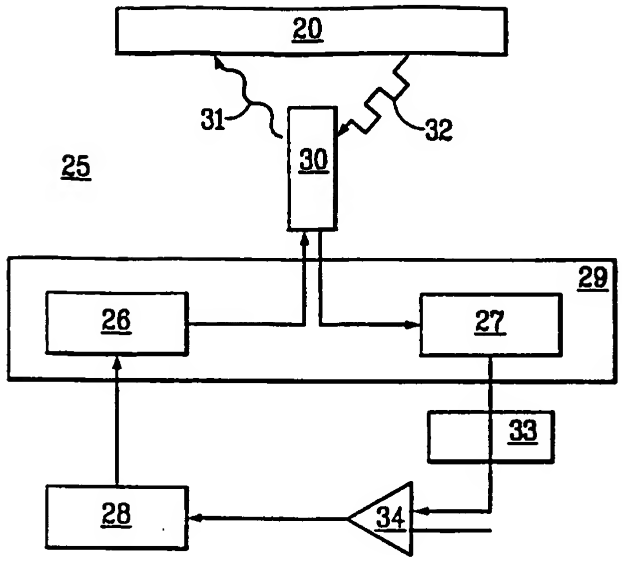


FIG. 7A

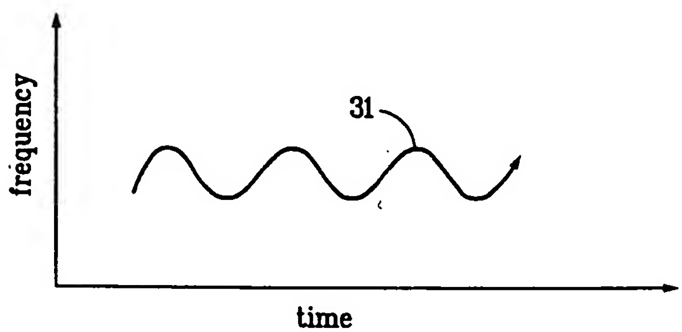
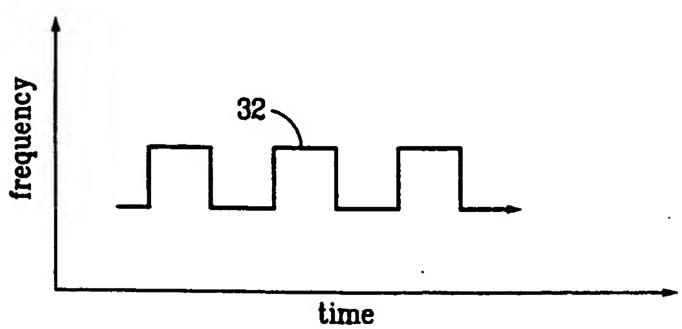


FIG. 7B



INTERNATIONAL SEARCH REPORT

Intern   ial Application No
PCT/US 00/17301

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G11B19/12 G11B23/00 G11B23/03 G11B23/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G11B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 809 245 A (TEXAS INSTRUMENTS INC) 26 November 1997 (1997-11-26) the whole document ---	1-8,12, 14,16, 18-24, 26,28-30
X	FR 2 762 429 A (ORDICAM) 23 October 1998 (1998-10-23) the whole document ---	1-8,11, 12,14, 16, 18-24, 26,28-30

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
27 October 2000	03/11/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Benfield, A

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/17301

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

Intern. .al Application No
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